Flexsem User Guide

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1 Introduction

The modeling framework Flexsem is a fast, flexible and very user friendly tool specifically targeted towards scientific and management challenges of the complex biogeochemical processes in coastal zone ecosystems. Flexsem is a modular marine modeling framework, which contains a simplified formulation of estuarine hydrodynamics and more complex descriptions of pelagic and benthic biogeochemical processes.

It has a very short computational time and can be easily adapted to different areas. Flexsem allows the user to set up computational grids of different complexity ranging from simple box model configurations to high-resolution unstructured grids. It can be applied by non-experts after a short introduction and might therefore be a good candidate to support managers and scientists without the need of an extensive computing infrastructure.

Questions? please contact Janus Larsen janl@dmu.dk

2 Generic definitions

Generic ways of inputting setup information is defined in this section. These definitions apply to multiple tags in the setup files. See the tag descriptions in the module sections for information about where the generic defintions can be used.

2.1 Initial values

Initial values can be defined as a numeric constant or by refering to a file that contains an initial field.

`<InitValue>` Numeric constant value.
`<InitFilename>` Path and name of file with initial values. Alternative to numerical value.
`<InitFileFormat>` File format. "TEXT0D", "TEXT1D" or "EMB". Mandatory for input from file.
`<InitItemNo>` Item number of item with initial values. Mandatory for input from file.

Numeric example

```
<InitValue>0.01</InitValue>
```

File example

```
<InitValue>
    <InitFilename>sediInit.emb</InitFilename>
    <InitFileFormat>EMB</InitFileFormat>
    <InitItemNo>0</InitItemNo>
</InitValue>
```

2.2 Selecting cells

Selecting specific cells in a 3D model can be done by giving a:

- layer number
- comma separated list of layers numbers
- path and name of file with layer numbers
- comma separated list of cell numbers
- path and name of file with cell numbers

`<Layers>` Define layer(s). "surface", "bottom", integer value or CSV list of integer values. `<Layers>` or `<Cells>` mandatory.
`<Filename>` Path and name of file with layer numbers.
`<Cells>` Define cell(s). Integer value or CSV list of integer values. Alternative to `<Layers>`.
`<Filename>` Path and name of file with cells numbers.

2.3 Passing constant values

Passing values constant in time to the model can be done by giving a:

- path and name of file with the values
- numeric
- comma separated list of numerics
- symbol of a constant (or a variable)

File example

```
<ConstantValues>
    <Filename>MyfileWithConstantValues.txt</Filename>
</ConstantValues>
```

Numeric example

```
<ConstantValues>3.14</ConstantValues>
```

Comma separated example

```
<ConstantValues>2,1.4142,6371</ConstantValues>
```

Symbol example

```
<ConstantValues>MySymbol</ConstantValues>
```

3 Modules

This sections contains a description of all Flexsem modules. All modules can run indpendently/are optional, unless otherwise stated. All date times must be given in the format "yyyy-MM-dd HH:mm:dd".

3.1 General

The purpose of the general section is to define the computationel domain in time and space. Mandatory.

`<General>` Definiton of model. Mandatory.
- `<Mesh>` Mandatory.
  - `<Filename>` Path to mesh file. Mandatory.
  - `<Format>` Format of mesh file. "EMT" (text) or "EMB" (binary). Mandatory.
  - `<Projection>` Projection string. "UTM32" or "LONLAT". Optional, default is "UTM32".
- `<Bathymetry>` Bathymetry. Mandatory.
  - `<Value>` Bathymetry values. Numeric (constant bathymetry), comma separated values or filename with one bathymetry value in each line.
  - `<Filename>` Bathymetry values. Filename with one bathymetry value in each line. Alternative to `<Value>`.
- `<DT>` The timestep in seconds. Mandatory.
- `<NoTimesteps>` Number of time steps. Default 0.
- `<NoLayers>` Number of layers. Ignored if the layer thickness is given as comma seperated values.
- `<LayerThickness>` Numeric. Sets all layers to given thickness. Mandatory.
- `<LayerThicknessCSV>` Comma separated list of layer thicknesses (NB from bottom up). If LayerType=="SIGMA", the sum of the layerthicnesses must equal 1. Alternative to `<LayerThickness>`
- `<LayerType>` The Layer type. "SIGMA" (default) or "Z".
- `<StartDT>` Start date and time. Default "1970-01-01 00:00:00".
- `<CheckBlowUp>` Indicates if the engine should check all varaibles in each time step for blow up values. "True" or "False (default).

Example

```
<General>
    <Mesh>
        <Filename>..\OneBox.mesh</Filename>
        <Format>EMT</Format>
    </Mesh>
    <Bathymetry>
        <Filename>..\OneBox.bathy</Filename>
    </Bathymetry>
    <NoLayers>1</NoLayers>
    <LayerThicknessCSV>1</LayerThicknessCSV>
    <LayerType>sigma</LayerType>
    <StartDT>2004-01-01 00:00:00</StartDT>
    <DT>3600</DT>
    <NoTimesteps>10</NoTimesteps>
</General>
```

3.2 SpecialValues

In this section symbols for model generated variables can be defined (each creates a new variable). These symbols can then be used as any other symbol, e.g. in an equation on in an output.

`<SpecialValues>`
- `<TimestepLengthSymbol>` Symbol for the time step length (=`<DT>` in `<General>`).
- `<PISymbol>` Symbol for Pi (=4*atan(1)=3.141593).
- `<TimestepNumberSymbol>` Symbol for the time step number.
- `<ElementAreaSymbol>` Symbol for the area all elements (2D).
- `<CellDepthSymbol>` Symbol for the depth of all cells (3D).
- `<CellVolumeSymbol>` Symbol for the volume of all cells (3D).
- `<Distance2Cell>` Distance to given cell.
  - `<Symbol>` Symbol for distance (3D). Mandatory.
  - `<CellNumber>` Integer cell number to the cell from which the distances are calculated. Mandatory.
- `<ElementCoordinates>` Element coordiantes (cell center).
  - `<XCoorSymbol>` Symbol for the element X coordinate (2D). Mandatory.
  - `<YCoorSymbol>` Symbol for the element Y coordinate (2D). Mandatory.

Example

```
<SpecialValues>
    <TimestepLengthSymbol>myDT</TimestepLengthSymbol>
    <PISymbol>myPI</PISymbol>
    <TimestepNumberSymbol>myTS</TimestepNumberSymbol>
    <CellDepthSymbol>cd</CellDepthSymbol>
    <CellVolumeSymbol>cv</CellVolumeSymbol>
    <Distance2Cell>
        <Symbol>dist2cell0</Symbol>
        <CellNumber>0</CellNumber>
    </Distance2Cell>
    <ElementCoordinates>
        <XCoorSymbol>eXCoor</XCoorSymbol>
        <YCoorSymbol>eYCoor</YCoorSymbol>
    </ElementCoordinates>
</SpecialValues>
```

3.3 Constants

Definition of 0D constants

```
<Constants>
  <Constant> Optionally multiple.
    <Symbol> Symbol of the constant (creates new 0D variable). Mandatory.
    <Value> Numerical value of the constant. Mandatory.
```

Example

```
<Constants>
    <Constant>
        <Symbol>gam</Symbol>
        <Value>0.8</Value>
    </Constant>
    <Constant>
        <Symbol>NHupmax</Symbol>
        <Value>1.22e-5</Value>
    </Constant>
</Constants>
```

3.4 Inputs

Read data from files into variables. Flexsem will automatically interpolate data from "TEXT0D" and "TEXT1D" formatted files in time and space.

```
<Inputs>
  <Input> Optionally multiple.
    <Filename> Path and name of file to read data from. Mandatory.
    <Format> File format. "TEXT0D", "TEXT1D" or "EMB", Mandatory.
    <Item> . Defines the item to read. If only one item in file, optionally leave out this tag.
      <Symbol> Symbol to read data into (creates new variable). Mandatory.
      <ItemNumber> Item number to read (zero based). Mandatory.
```

Example

```
<Inputs>
    <Input>
        <Filename>kattegatBndT_2.emb</Filename>
        <Format>EMB</Format>
        <ItemNumber>0</ItemNumber>
        <Symbol>bnd2t</Symbol>
    </Input>
    <Input>
        <Filename>..\data\HBMriver4_Flexsem.txt</Filename>
        <Format>TEXT0D</Format>
        <Item>
            <ItemNumber>0</ItemNumber>
            <Symbol>src4aa</Symbol>
        </Item>
        <Item>
            <ItemNumber>4</ItemNumber>
            <Symbol>src4oo</Symbol>
```

```
        </Item>
    </Input>
</Inputs>
```

3.5 HD

Decoupled hydrodynamics.

<HD>
- <Decoupled> Decoupled hydrodynamics
  - <InputFilename> Path and name of the file with velocities and fresh water fluxes for the decoupling. Mandatory.
  - <UItemNumber> Item number of the face velocities. Default 0.
  - <SourceItemNumber> Item number of the source fluxes. Default 1.
  - <NumberSubcycles> The number of times to subcycle the advection in each timestep (linear interpolation of velocities). Default 1.
- <HorisontalDiffusivity> Horisontal diffusivity. Default 0.
- <VerticalDiffusivity> Vertical diffusivity. Default 0.

Example

```
<HD>
    <Decoupled>
        <InputFilename>kattegatVel2010.emb</InputFilename>
        <NumberSubcycles>5</NumberSubcycles>
    </Decoupled>
    <HorisontalDiffusivity>0</HorisontalDiffusivity>
    <VerticalDiffusivity>0</VerticalDiffusivity>
</HD>
```

3.6 HDLite

This module contains simplified formulations of estuarine and fjord dynamics including advection, horizontal and vertical mixing. It employs a time-dependent, combined boxmodel and 3-D model approach. Water mass exchange in the HDLite module is realized in the form of volume fluxes between the mesh cells, formulated as an exchange volume per time unit scaled by the time step of the model. Fluxes between mesh cells are automatically calculated from the computational mesh geometry. See Janus Larsen, Christian Mohn, Karen Timmermann, A novel model approach to bridge the gap between box models and classic 3D models in estuarine systems, Ecological Modelling, Volume 266, 24 September 2013, Pages 19-29, ISSN 0304-3800, http://dx.doi.org/10.1016/j.ecolmodel.2013.06.030. Alternative to <HD>

<HDLite>
- <CalcDens> If true, adds variable 'dens' and calculates density from salinity and temperature in each timestep. "True" or "False".
- <InitialSaltValue> Initial value for salinity. See section 2.1
- <Temperature>
  - <InitialValue> Initial value for water temperature. See section 2.1
  - <AirTemperature> Numerical value or symbol for air temperature.
- <HorisontalMixing> Numeric for constant horisontal mixing. Default: 0.
  - <Value> Horisontal mixing coefficient. Alternative to constant horisontal mixing.
  - <ConstantHM> If "True" do not scale horisontal mixing with cell volume. This makes the horisontal mixing in each time step propotional to the area on the cell interface overlap and

there by more 'current like' (small overlap -¿ small exchange). If "false" the mixing scales with the total volume of the cell. Default: "False".
<WindSpeedCoef> Wind dependent mixing coefficent component.
<WindSpeed> Numeric or symbol for wind speed. Mandatory if <WindSpeedCoef>.
<MaxMixDirection> Wind direction of maximum mixing coefficent.
<WindDirection> Numeric or symbol for wind direction. Mandatory if <MaxMixDirection>.
<Wind> Wind speed dependent vertical mixing. Default: No vertical mixing.
<Speed> Numeric or symbol for wind speed. Mandatory.
<AirDensity> Air density. Default: 1.293 kg/m3.
<CoriolisParameter> Coriolis parameter. Default: 0.0001.
<WaterDensity> Density of water. Default: 1000 kg/m3.
<AttenuationDepth> Attenuation depth of veritical mixing. Default: 10 m.

Example

```
<HDLite>
    <InitialSaltValue>
        <InitFilename>..\initSalt.emb</InitFilename>
        <InitItemNo>0</InitItemNo>
        <InitFileFormat>EMB</InitFileFormat>
    </InitialSaltValue>
    <Temperature>
        <InitialValue>0</InitialValue>
        <AirTemperature>airtemp</AirTemperature>
    </Temperature>
    <HorisontalMixing>
        <Value>2e-03</Value>
      <WindSpeed>ws</WindSpeed>
        <WindSpeedCoef>0</WindSpeedCoef>
        <WindDirection>wd</WindDirection>
        <MaxMixDirection>-15</MaxMixDirection>
    </HorisontalMixing>
    <Wind>
        <DragCoef>1e-07</DragCoef>
        <AirDensity>1.293</AirDensity>
        <Speed>ws</Speed>
        <CoriolisParameter>0.0001</CoriolisParameter>
        <WaterDensity>1000</WaterDensity>
        <AttenuationDepth>6</AttenuationDepth>
    </Wind>
</HDLite>
```

3.7 Flexsem

3D pelagic equation solver.

<Flexsem>
<DisableGroupCSV> Comma separated list of group names to disable. Names must match "Group" attribute in <Variable> or <Equation>
<Variables>
<Variable> Optionally multiple. Optionally group attribute: <Equation Group="MyGroup">.
<Symbol> Variable symbol. Mandatory.

<Advect> Indicates if the variable should be advected (by HD or HDLite). "True" or "False" (default).
<NotNegative> Indicates if Flexsem should truncate negative values to 0. "True" or "False" (default).
<InitValue> Initial value for the variable. See section 2.1
<Equations>
<Equation> Optionally multiple. Optionally group attribute: <Variable Group="MyGroup">.
<Definition> Equation definition. Mandatory.
<Description> Equation description. Does not affect the model.
<MappedOperation> Move a fraction of one variable in specific cells to another variable in optionally an other set of specific cells. Used to model a patchy process moving stuff from the pelagic to the sediment (or vica versa). Optionally multiple.
<From> Defines what to map from. Mandatory.
<Variable> Symbol of the variable to map from. Mandatory.
<Fraction> The fraction of the variable to move assuming that the variable represents a concentration. Must be same length as the number of given cells. See section 2.3 . Mandatory.
<Cells> Cells to map from. See section 2.2. <Layers> or <Cells> mandatory.
<Layers> Give the cells to map from as layers. See section 2.2. Alternative to Cells.
<To> Defines what to map to. Mandatory.
<Variable> Symbol of the variable to map to. Mandatory.
<Cells> Cells to map to. Length must equal <From> length. See section 2.2. <Layers> or <Cells> mandatory.
<Layers> Give the cells to map to as layers. See section 2.2. Alternative to Cells.
<DumpSystemAsRCode> Write a file with the equation system as R code.
<CellNo> Cell number to use in equation system. Mandatory.
<FileName> Path and name of file to output code to. Mandatory.

Example

```
<DisableGroupCSV>B</DisableGroupCSV>
<Flexsem>
    <Variables>
        <Variable>
            <Symbol>A</Symbol>
            <Description>My A variable</Description>
            <InitValue>1</InitValue>
        </Variable>
        <Variable Group="B">
            <Symbol>B</Symbol>
            <Description>My z variable</Description>
            <InitValue>1</InitValue>
        </Variable>
        <Variable>
            <Symbol>C</Symbol>
            <Description>My C variable</Description>
            <InitValue>0</InitValue>
        </Variable>
    </Variables>
    <Equations>
        <Equation Group="B">
            <Definition>B=A*C</Definition>
            <Description>Test</Description>
        </Equation>
```

```
        <Equation>
            <MappedOperation>
                <From>
                    <Variable>A</Variable>
                    <Layers>Bottom</Layers>
                    <Fraction>0.1</Fraction>
                </From>
                <To>
                    <Variable>C</Variable>
                    <Cells>Bottom</Cells>
                </To>
            </MappedOperation>
        </Equation>
    </Equations>
</Flexsem>
```

3.8 EcoLight

Parameterization and calculation of light attenuation. The module adds the variable "I" to the model. I is calucated as I = I0*exp(-kd*d) , where d is the cell center depth, I0 = (1-k5)*v4 and kd = k1-k2*v1+k3*v3+k4*k6*v3 This non-intuitive formulation has historic origins.

`<EcoLight>`
- `<v1>` Variable symbol.
- `<v2>` Variable symbol.
- `<v3>` Variable symbol.
- `<v4>` Variable symbol. Mandatory.
- `<k1>` Numeric. Default 0.
- `<k2>` Numeric. Default 0.
- `<k3>` Numeric. Default 0.
- `<k4>` Numeric. Default 0.
- `<k5>` Numeric. Default 0.
- `<k6>` Numeric. Default 0.
- `<AddkDasVariable>` If "True" adds a new variable with symbol "kD" were kd values are stored.
- `<kdSymbol>` Symbol for new variable were kd values are stored.

Example

```
<EcoLight>
    <v1>salt</v1>
    <v2>C</v2>
    <v3>X</v3>
    <v4>glorad</v4>
    <k6>1</k6>
    <k1>1.5</k1>
    <k2>0.06</k2>
    <k3>0</k3>
    <k4>0.1</k4>
    <k5>0.55</k5>
    <kdSymbol>kd</kdSymbol>
</EcoLight>
```

3.9 EcoSediment

Benthic equation solver (sediment model) including multiple layers (3D), sedimentation, diffusion. The horisontal computation mesh is the same as the one defined in the <General> section 3.1.

<EcoSediment>
- <General> Defines the
  - <NoLayers> Number of layers. Mandatory.
  - <LayerThicknessCSV> Comma separated list of layer thicknesses (NB from bottom up). If LayerType=="SIGMA", the sum of the layerthicnesses must equal 1. Mandatory.
  - <Bathymetry> Bathymetry. Mandatory.
    - <Value> Bathymetry values. Numeric (constant bathymetry), comma separated values or filename with one bathymetry value in each line.
    - <Filename> Bathymetry values. Filename with one bathymetry value in each line. Alternative to <Value>.
  - <Run> Indicates if the sediment module modifies the valures in each time step (model on/off). "False" or "True" (default).
- <PelagicVariables> Use values from bottom layer of a pelagic variable in all layers of the sediment. E.g. Temperature.
  - <Variable> Optionally multiple.
    - <Symbol> Symbol of new benthic variable. Mandatory.
    - <PelagicVariable> Symbol of pelagic variable to copy values from. Mandatory.
- <Diffusion> Diffuse transport between bottom pelagic layer and surface benthic layer.
  - <DiffusionLength> The diffusion length to use. Default 0.1.
  - <DiffusionCoef> Default diffusion coefficient. Default 0.
  - <Variable> Optionally multiple.
    - <Symbol> Symbol of new benthic variable. Mandatory.
    - <InitValue> Initial value of benthic variable. If omitted, the benthic varible will inherit the pelagic variables initial value. See section 2.1
    - <NotNegative> Indicates if negative values are truncated to 0. "True" or "False" (default).
    - <PelagicVariable> Symbol of existing pelagic variable to diffuse with. Mandatory.
    - <DiffusionCoef> Diffusion coefficient for current variable which overrides the default diffusion coefficient.
    - <FluxSymbol> Add 2D variable with given symbol were the flux tranported across the pelagic/benthich interface is stored.
- <Sedimentation> Enables sedimentation/vertical advection.
  - <PelagicVerticalVelocity> Default fall rate in the pelagic. NB positive upwards. See section 2.3
  - <BenthicVerticalVelocity> Default fall rate in the sediment. NB positive upwards. See section 2.3
  - <UsePelagicBottomVinTopSediment> If true, use pelagic bottom vertical velocity in top of sediment. This causes the pelagic to sedimentate into the surface sediment layer. "True" or "False" (default).
  - <Variable> Optionally multiple.
    - <PelagicVerticalVelocity> Fall rate in the pelagic for this variable only (overriding default value). NB positive upwards. See section 2.3
    - <BenthicVerticalVelocity> Fall rate in the sediment for this variable only (overriding default value). NB positive upwards. See section 2.3
    - <Symbol> Symbol of new benthic variable. Mandatory.
    - <InitValue> Initial value of benthic variable. See section 2.1
    - <NotNegative> Indicates if negative values are truncated to 0. "True" or "False" (default).

`<PelagicVariable>` Symbol of existing pelagic variable to enable sedimentation for. Mandatory.

`<Variables>` Same as for pelagic equation solver. See section 3.7.

`<Equations>` Same as for pelagic equation solver. See section 3.7.

Example

```
<EcoSediment>
    <General>
        <Run>true</Run>
        <NoLayers>2</NoLayers>
        <LayerThicknessCSV>0.5,0.5</LayerThicknessCSV>
        <Bathymetry>
            <Value>0.1</Value>
        </Bathymetry>
    </General>

    <PelagicVariables>
        <Variable>
            <Symbol>botV1</Symbol>
            <PelagicVariable>V1</PelagicVariable>
        </Variable>
    </PelagicVariables>

    <Diffusion>
        <DiffusionLength>0.1</DiffusionLength>
        <DiffusionCoef>1e-5</DiffusionCoef>
        <Variable>
            <DiffusionCoef>1e-8</DiffusionCoef>
            <Symbol>sediA</Symbol>
            <InitValue>0</InitValue>
            <PelagicVariable>A</PelagicVariable>
        </Variable>
    </Diffusion>

    <Sedimentation>
        <PelagicVerticalVelocity>-1e-5</PelagicVerticalVelocity>
        <BenthicVerticalVelocity>-1e-7</BenthicVerticalVelocity>
        <UsePelagicBottomVinTopSediment>true</UsePelagicBottomVinTopSediment>
        <Variable>
            <Symbol>sediC</Symbol>
            <InitValue>0</InitValue>
            <PelagicVariable>C</PelagicVariable>
        </Variable>
    </Sedimentation>

    <Variables>
        <Variable>
            <Symbol>sediV2</Symbol>
            <InitValue>0</InitValue>
        </Variable>
    </Variables>

    <Equations>
```

```
        <Equation>
            <Definition>sediV2=botV1-sediC</Definition>
            <Description></Description>
        </Equation>
    </Equations>
</EcoSediment>
```

3.10 Sources

Adds fresh watersources including concentrations of pelagic variables.

`<Sources>`
- `<Source>` Optionally multiple.
  - `<Symbol>` Source symbol. Mandatory.
  - `<ElemNo>` Element number to add source to. Mandatory.
  - `<Flux>` Numeric or symbol that defines the fresh water flux. Mandatory for non-decoupled sources.
  - `<Description>` Source description.
  - `<LayerNo>` Layer number to add source to. Default is surface layer.
  - `<Variable>` Optionally multiple.
    - `<Symbol>` Symbol of the pelagic variable to modify. Mandatory.
    - `<Concentration>` Numeric or symbol that defines the concentration of the pelagic variable in the fresh water. Mandatory.
    - `<ConcentrationFactor>` Numeric or symbol that defines a factor that the concentration is multiplied by. Optional. Default=1.

Example

```
<Sources>
    <Source>
        <Symbol>s1</Symbol>
        <Description>Source 1 water flux [m3/s]</Description>
        <ElemNo>7</ElemNo>
        <Flux>fwi</Flux>
        <Variable>
            <Symbol>salt</Symbol>
            <Concentration>0</Concentration>
        </Variable>
    </Source>
  <Source>
        <Symbol>s2</Symbol>
        <Description>Source outer east</Description>
        <ElemNo>0</ElemNo>
        <Flux>fwoe</Flux>
        <Variable>
            <Symbol>salt</Symbol>
            <Concentration>0</Concentration>
        </Variable>
        <Variable>
            <Symbol>NO3</Symbol>
            <Concentration>src2NO3</Concentration>
        </Variable>
    </Source>
<Sources>
```

3.11 Boundaries

Defines open boundary conditions.

<Boundaries>
  <Boundary> Optionally multiply.
    <Number> Boundary number. Must match an open boundary number in the mesh. Mandatory.
    <ExchangeRate> Numeric. Boundary exchange rate [m3/s]. HDLite only.
    <WindDirection> Numeric or symbol. Modifies the exchange rate as a function of wind direction. HDLite only.
    <MaxExchangeDirection> Numeric. Direction of maximum exchange. HDLite only. Mandatory if <WindDirection> present.
    <Variable> Optionally multiple. NB: all advected variables must be defined on all open boundaries.
      <Symbol> Symbol of the pelagic variable to modify. Mandatory.
      <Concentration> Numeric or symbol that defines the concentration of the pelagic variable on the boundary. Mandatory.

Example

```
<Boundaries>
    <WindDirection>wd</WindDirection>
    <MaxExchangeDirection>0</MaxExchangeDirection>
    <ExchangeRate>300</ExchangeRate>
    <Boundary>
        <Number>1</Number>
        <Variable>
            <Symbol>salt</Symbol>
            <Concentration>saltbnd</Concentration>
        </Variable>
        <Variable>
            <Symbol>temp</Symbol>
            <Concentration>tempbnd</Concentration>
        </Variable>
    </Boundary>
</Boundaries>
```

3.12 SurfaceExchanges

Adds surface exchanges e.g. precipitation/eveporation, or modifies other pelagic state variables in the surface.

<SurfaceExchanges>
  <SurfaceExchange> Optionally multiple.
    <AtmosContribution> Numeric or symbol. Rate of loss/gain.
    <PelagicSymbol> Symbol of pelagic variable to modify. Mandatory if <AtmosContribution> present.
    <Precipitation> Numeric or symbol. Modify surface salinity by precipitation/evaporation.
    <SaltSymbol> Salinity symbol. Mandatory if <Precipitation> present.

Example

```
<SurfaceExchanges>
    <SurfaceExchange>
        <AtmosContribution>3.4e-6</AtmosContribution>
        <PelagicSymbol>NO3</PelagicSymbol>
    </SurfaceExchange>
    <SurfaceExchange>
        <Precipitation>precip</Precipitation>
        <SaltSymbol>salt</SaltSymbol>
    </SurfaceExchange>
</SurfaceExchanges>
```

3.13 SurfaceOxygen

Calculates oxygen saturation in surface layer following Stæhr, Peter Anton et al."Lake metabolism and the diel oxygen technique: State of the science". Limnology and Oceanography: Methods. 2010, 8. 628-644. Available: 10:4319/lom.2010.8.628

`<SurfaceOxygen>` Modifies surface oxygen.
- `<OxygenSymbol>` Symbol of pelagic oxygen variable to modify. Mandatory.
- `<Salinity>` Salinity symbol or numeric. Mandatory.
- `<Temperature>` Water temperate symboll or numeric. Mandatory.
- `<WindSpeed>` Wind speed symboll or numeric. Mandatory.
- `<UnitFactor>` Oxygen saturation is calculated in ml O2/l. This is the conversion factor to the oxygen unit that your model uses. Default 44.661 which is the conversion factor between ml O2/l to mmol O2/m3 following ocean.ices.dk/Tools/UnitConversion.aspx.

Example

```
<SurfaceOxygen>
    <OxygenSymbol>O2</OxygenSymbol>
    <Salinity>salt</Salinity>
    <Temperature>temp</Temperature>
    <WindSpeed>ws</WindSpeed>
    <UnitFactor>44.61</UnitFactor>
</SurfaceOxygen>
```

3.14 Sections

Calculate fluxes through user defined vertical sections. The flux is calculated positively to the right when walking along the section in the order that the nodes numbers are given.

`<Sections>`
- `<Section>` Define new section to calculate flux through. Optionally multiple.
  - `<NodeNumberCSV>` Comma separated list of node numbers that defines the section. The node numbers must be connected by a face. Mandatory.
  - `<FluxCalc>` Calculate flux of specific variable through the section. Optionally multiple.
    - `<Symbol>` Symbol of new 0D variable to hold result of flux calculation. Mandatory.
    - `<PelagicSymbol>` Symbol of pelagic variable to calculate flux for. Mandatory.

Example

```
<Sections>
    <Section>
        <NodeNumberCSV>142,300,264,41</NodeNumberCSV>
        <FluxCalc>
            <Symbol>saltflux</Symbol>
            <PelagicSymbol>salt</PelagicSymbol>
        </FluxCalc>
    </Section>
</Sections>
```

3.15 Outputs

Output variable values to files. Each file can only contain variable of the same dimenstion, i.e. you cannot output e.g. 2D and 3D variables to the same file.

`<Outputs>`
- `<Output>` New output. Optionally multiple.
  - `<Filename>` Output filename. Mandatory.
  - `<Format>` Format of output file. "EMT" (tab separated), "EMF" (fixed width) or "EMB" (binary). Mandatory.
  - `<TimestepFrom>` The first time step to output. Default 0.
  - `<TimestepTo>` The last time step to output. Default is all time steps.
  - `<TimestepInterval>` The interval between outputted time steps. Default 1.
  - `<CellNoCSV>` Integer array of cell number to output. Default is to output all cells.
  - `<FixedWidthFieldWidth>` Width of the fields in fixed width format. Default 12.
  - `<Variable>` The symbol of the variable to output. Optionally multiple. Optionally average attribute: `<Variable Average="True">` to average values over `<TimestepInterval>` timesteps.

Example

```
</Outputs>
    <Output>
        <Filename>InOutAvg.txt</Filename>
        <TimestepFrom>0</TimestepFrom>
        <TimestepTo>-1</TimestepTo>
        <TimestepInterval>4</TimestepInterval>
        <Format>EMF</Format>
        <FixedWidthFieldWidth>14</FixedWidthFieldWidth>
        <Variable Average="true">ws</Variable>
        <Variable>ws</Variable>
        <Variable>wd</Variable>
    </Output>
    <Output>
        <Filename>LaholmsbuktenVelOneDay3D.emb</Filename>
        <Format>EMB</Format>
        <Variable>TRC</Variable>
    </Output>
    <Output>
        <Filename>LaholmsbuktenVelOneDay2D.emb</Filename>
        <Format>EMB</Format>
        <Variable>h</Variable>
    </Output>
</Outputs>
```